

Design and usability evaluation of an audio-based college entrance exam for students with visual disabilities

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ABSTRACT

The purpose of this research was to design, implement and evaluate the usability of a digital pilot system that adapts the Language and Communication subject section of the PSU (Chilean college entry exam), allowing for equal and autonomous participation by learners with visual disabilities in the college selection process. The study was carried out in two stages during the years 2010 and 2012. The pilot project was carried out in December of 2010 in three different regions of Chile, at the same time as the regular process for taking the PSU. Based on the initial results from 2010, the system was redesigned, implemented and evaluated in order to create the final version. The results for the final version of the tool designed demonstrate a high level of usability. This work provides a detailed analysis and discussion of the results obtained in 2012, as well as future directions regarding the issue at hand.

1. INTRODUCTION

According to the WHO 2014, there are approximately 285 million people in the world with visual disabilities, of which 39 million are blind. The geographic distribution of this disability is not uniformly distributed throughout the world, and approximately 90% of people with visual disabilities live in developing countries.

In Chile, the results of the CASEN 2011 survey indicate that 6,3% of the population has at least some degree of disability, in which the most frequent disability corresponds to blindness or visual difficulties (15,4%), even when using glasses (Ministry of Social Development, 2014).

Education in Chile is a sensitive issue for people with disabilities, for which reason their integration must take place as soon as possible. The ENDISIC 2004 survey showed that while 27.5% of the general population is currently in school, among the disabled population this shrinks to only 8.5% (Senadis, 2004).

In order to implement educational integration of this population in Chile, the School Integration Project (PIE, for its Spanish acronym) emerged. PIE is a school system strategy with the objective of contributing to the continuous improvement of the quality of education provided in the school system, encouraging higher classroom attendance, participation in the learning process, and the learning of expected lessons for all students, with a special focus on those with special educational needs, whether of a permanent or temporary nature (Mineduc, 2012).

In the admissions process for Chilean universities (directed by the council of rectors), a standardized testing instrument called the University Selection Test (PSU, for its Spanish acronym), is utilized in order to measure student knowledge and skills in various educational subjects: Language and Communication, Mathematics, History and Social Science, and Science. The procedure for the use of this instrument traditionally involves a paper and pencil based test, which restricts the options for people who are blind to be able to participate in the regular testing process.

There is evidence of initiatives to integrate participants with visual disabilities into normal test-taking processes from other countries. Kaczmarek and Wolff (2007) presented guidelines for the design of self-administered surveys for people with visual disabilities including people who are blind within a mixed mode approach (paper-based, Braille-based, and Web-based). Katoh (2002) researched the use of tactile graphics in the entrance exams for Japanese universities, obtaining the result that learners who are blind are able to take tests with tactile graphics, but require more time to answer the questions than people with normal vision. Another

possibility to balance this aspect is to eliminate the questions with graphics, as is done in the Swedish Scholastic Aptitude Test (Katoh, 2002). In Japan, work has been done incrementally on a system of evaluation for users who are newly blind and also have problems with dyslexia, so that they are able to take the National Center Test for University Admissions (Fujiyoshi and Fujiyoshi, 2006; Fujiyoshi et al, 2010, 2012). In India, special science exams in physics, chemistry, biology and mathematics were announced for 2012 and 2013 (Higher Education in India, 2011). These tests are adapted for students with visual disabilities by excluding visual elements such as diagrams or graphics. In China in 2002, the possibility was opened for students who are blind to be integrated into the regular process for the national university entrance examination (China, 2002). In Brazil, Article 27 of Decree N°3.298 (Brasil, 1999) defines that higher education institutions should offer adapted tests as well as the necessary support when previously requested by a student with disabilities, including additional time to take the tests, in accordance with the characteristics of the particular disability. For test takers who are blind, universities even offer the use of handheld magnifying glasses, tests with enlarged print, tests given in Braille, and even tests given orally by special aids trained for this purpose. Despite this advanced level of special attention, the test taker who is blind does not take the test in the same place along with the other candidates, as they require special test taking spaces, and sometimes even take the exam on a different date and at different times as the normal exam. In addition, it may be difficult for test takers who are blind to manage the Braille test (imagine having to read a 20-page test in Braille, for example, and the difficulties related to asking for help on specific test questions and reviewing one's answers), to understand the pronunciation of readings for translation into another language, or even to describe the images printed on the test.

In this context, the purpose of this research was to design, implement and evaluate the usability of a digital pilot system that adapts the PSU in the subject of Language and Communication, allowing for equal and autonomous participation by people with visual disabilities in the college selection process.

The study was carried out in two stages during the years 2010 (Sánchez and Espinoza, 2012) and 2012. The pilot project was carried out in December of 2010, at the same time as the regular process for taking the PSU. This pilot was performed in three different regions at the same time. Based on the initial results from 2010, the system was redesigned, implemented and evaluated in order to create the final version. This work provides a detailed analysis and discussion of the results obtained in 2012, as well as future directions regarding the issue at hand.

2. AUDIOPSU SYSTEM (FINAL VERSION)

From the beginning, the design of the system considered: (i) No special spatial requirements needed to take the test; (ii) Development of an adapted, standardized, knowledge measurement instrument; (iii) No student aides needed to take the test; and (iv) Provision of the same advantages that sighted people have in being able to navigate between the various test questions (Sánchez and Espinoza, 2012).

The AudioPSU System was first presented in (Sánchez and Espinoza, 2012). The system consists of an adaptation of the Language and Communication PSU, which is organized into 3 different sections: I) Knowledge of basic concepts and general language and communications skills, II) Text production indicators, III) Reading comprehension.

There are four different kinds of questions with varying specific formats included in the PSU Language and Communication subject test. Section I groups questions of the same kind. Section II has 2 sub-sections: A) Managing connectors and B) Writing plan, in which each sub-section groups a certain kind of question format that is different from the other sections. Finally, section III is subdivided into various groups of questions, in which each group includes a common text made up of various paragraphs, which serves to resolve and answer reading comprehension questions for each group.

The interaction with AudioPSU for the user with visual disabilities takes place through the use of a numpad, allowing users with visual disabilities to navigate between the various interfaces provided by the software. The "Index" interface allows the user to select a particular question and see if it has been answered or not, and the structure of the "Question" interface allows the user to identify elements of the question such as the question phrase, complementary texts and the answer choices. Finally, the system provides information regarding navigation through the text in order to resolve the questions through text-to-speech (TTS), which can be heard through stereo headphones.

The results of the pilot system implemented in 2010 (Sánchez and Espinoza, 2012) led to a series of improvements, changes and upgrades to the final version of the AudioPSU system, which are described below.

2.1 Software upgrades

The final version of the software works with two different voices, mainly in order to be able to adequately differentiate between the enunciation of the question and the answer choices. The enunciation of a question (as

well as the other parts of the test) uses a specific voice for reading the texts. The answer choices are given with a specifically assigned second voice. When the user enters into the answer choice section, the enunciations change to the second voice. When returning to the question, the enunciations change back to the first voice. This change was implemented for all of the questions.

In some cases there are words that are highlighted within the questions, which on the paper copy of the PSU are either underlined or written in bold print. In order to highlight these words, a series of changes were added by writing these words in capital letters and including quotation marks, spaces and commas before and after the words to be highlighted. With these modifications, the reading software (TTS) accentuates the words by increasing the tone of the voice and pausing both before and after the highlighted word. In this way, it is possible to note a break in the flow of the enunciation, clearly demarcating the highlighted word. This change makes it much easier to recognize which words are highlighted in the spoken text.

In addition, an advanced function was incorporated called the matrix navigation mode, which consists of a special way of navigating the questions regarding the management of connectors and writing plans. Essentially, this function serves to navigate the paragraphs or parts of a text as determined by the characteristics of the question.

In the case of the questions regarding the management of connectors, by defect the enunciation of the question presents a text with blank spaces for which connectors must be chosen. In the answer choices different connectors are presented as options to insert into the blank spaces included in the body of the question. In order to activate the matrix navigation mode, the user must be located within one of the answer choices. When this modality is activated, the user can navigate sequentially (backwards and forwards) through the various parts of the sentence, which are determined or segmented based on the position of the blank spaces in the sentence. For example, in a question with two connectors, first the entire first part of the text before the first blank space is read, then the first connector is presented as an answer choice, followed by the following bit of text, next the second connector, ending with the final part of the text. This allows the user to test out the use of the connectors presented as answer choices inserted into the text of the question.

In the case of the questions regarding the writing plan, by defect the spoken text consists of a series of paragraphs including numbered texts (usually between 4 and 6 numbers), and the answer choices present different options regarding the correct order of the text. For example, for a question with 4 paragraphs, one answer choice might be 2-4-3-1. In order to activate the matrix navigation mode the user can listen to the paragraphs in the order proposed by the answer choices sequentially (forwards and backwards). For example, if the answer choice is 2-4-3-1, in proceeding sequentially through the choice the system will read the paragraphs step by step, starting with the second paragraph, moving on to the fourth, from there on to the third, and ending with the first paragraph. In addition, the user can go backwards sequentially in order to reread the paragraphs. For example, if paragraph 3 is being read, the user can choose to move backwards to paragraph 4. This helps the user to read the texts in the order suggested in the answer choice, so that he or she can determine if this order is correct.

2.2 Hardware improvements

The system consists of: (i) A Netbook with the software that adapts the PSU Language and Communication test; (ii) Stereo headphones to provide information to the user (output); and (iii) A Numpad in order to execute the system's actions (input). Each functional key on the numpad has an associated Braille symbol to make it recognizable to users who are blind (Sánchez and Espinoza, 2012).

The numeric keyboard or numpad works as an entry interface for the user. The marks on the functional keys were adapted to incorporate Macrotype and Braille labels together with the sign or letter that corresponds to the given function (see Fig. 1). In this way, a user who is blind or a user with low-level vision can use the same device. This adjustment was made considering the special educational needs of the entire population with visual disabilities, as there are people with low level vision that use Braille, people who are blind who also use Braille, and people with low level vision who use Macrotype. The non-functional keys were blocked (or ignored) by the software, in order to avoid confusion among the users. Another adjustment to the keyboard was the extraction of the "Block Num" key, as this transforms the function of the numeric keyboard, deactivating the numbers associated to the functions utilized in the system.

The keys were grouped together as Navigation, Consultation or Fast Navigation keys according to their functionality:

Navigation Keys:

- "s" Key. Move up from a question to the section, from a sub-section to the section, from a group to the section, move up from a question to the sub-section, and from a question to the group.

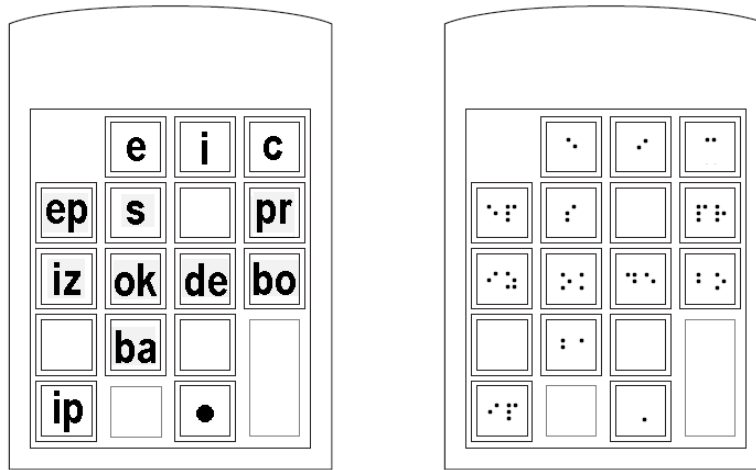


Figure 1. Keyboard scheme with Macrotype and Braille markings utilized in the AudioPSU system.

- “iz” Key. Move to the left between sections, sub-sections, groups or questions.
- “ok” Key. Enter into the desired question, section or sub-section.
- “de” Key. Move to the right between sections, sub-sections, groups or questions.
- “ba” Key. Go down from the section to a question or from a sub-section to a question, and move down from a group to a question.
- “ep” Key. Enter into the matrix mode of navigation between paragraphs of a text. This key will be useful for: (i) navigating between the parts of a sentence using the “iz” and “de” keys (connectors management); (ii) listening to the answer choices of the different statements in order, navigating with the “iz” and “de” keys (writing plan); (iii) at any time it is possible to leave the matrix navigation mode by pressing the “ep” key.

Consultation Keys:

- “ip” Key. Start listening to the paragraph, statement, question or answer choice if the user wants to hear it again.
- “•”Key. Listen to the information regarding where the user is located in the test.

Fast Navigation Keys:

- “e” Key. Listen to the instructions for each section of the test.
- “i” Key. Go to the test index for the section or question where the user is located.
- “c” Key. Go to the beginning of the test index (Section 1).
- “pr” Key. Go directly to the question. A window is opened in which the user can write the number of a specific question (with the same numeric keyboard), and when pressing it again the user will be taken directly to that question. In the case of making a mistake when writing the number, it can be erased by using the “bo” key located below the “pr” key. In order to utilize the numbers, it must be taken into account that the numbers are mapped according to their location by defect on the numpad.
- “bo” Key. Erase the question number selected when the function for going directly to a question has been activated.

3. USABILITY EVALUATION (PILOT 2012)

To be able to evaluate the usability of the final version of the tool, a second pilot was performed in 2012. Just as in the 2010 evaluation (Sánchez and Espinoza, 2012). This second evaluation was carried out with the end users who are blind of the system, aiming mainly to validate the tool and to detect any problems and issues with its effective use. This was done in order to be able to compare the results and to measure the effect of the improvements that had been incorporated into the final version. The details of the usability evaluation performed for the 2012 pilot are described below.

3.1 Sample

The sample utilized for the usability evaluation in 2012 was chosen among students who shared the requisite characteristics of being between sophomore and senior level of high school, or being high school graduates in

general. The sample was made up of a total of 11 people with visual disabilities. Of this total, 4 were female and 7 were male, with ages ranging from 17 to 55 years old, and all of who are residents of Santiago, Chile. The sample characteristics was equivalent to the one used in the 2010 usability evaluation.

3.2 Instruments

The same user satisfaction evaluation questionnaire regarding the use of the software (Sánchez and Espinoza, 2012) was utilized for the end user evaluation, which consisted of an adaptation of the end user questionnaire “Software Usability Evaluation” designed by Sánchez (2003). This questionnaire is divided into two sections: In the first section, the users are asked to evaluate 12 statements related to the use of the software, on a scale of 1 to 10, in which 1 corresponds to ‘very unsatisfactory’ and 10 corresponds to ‘very satisfactory’. The sentences were the following: (1) “I like the software”, (2) “The software is fun”, (3) “The software is challenging”, (4) “The software is motivating”, (5) “The software helps me to be active”, (6) “I felt I could control the situations in the software”, (7) “The software is interactive”, (8) “The software is easy to use”, (9) “The software adjusts to my rhythm”, (10) “I like the sounds in the software”, (11) “The sounds of the software are clearly identifiable” and (12) “The sounds of the software give me information”. In the second section, the users are presented with 6 open-ended questions, such as: “What did you like about the software?”, “What did you dislike about the software?”, “What would you add to the software?”, “What do you think is the use of the software?”, “Which other uses could you make of the software?” and “Did you like to use the numpad? Why or why not?”. Also, an additional space was added to allow the users to express any opinions that they considered to be significant, and that they felt had been left out of the questionnaire.

It is important to point out that the 12 statements in this questionnaire were grouped according to 3 dimensions: Satisfaction (1, 2, 3, 4), Control and Use (sentences 5, 6, 7, 8, 9), and Sounds (sentences 10, 11, 12). When processing the results, an indicator for each dimension was calculated, corresponding to the average response given to the questions in each group. The results provide the indicators obtained for each dimension.

Together with this questionnaire, the teacher facilitators of the pilot experience also utilized a Non-Participant Observer questionnaire. Using this questionnaire, the facilitators recorded the following aspects for each user: start time and finish time of the experience, user’s location in the room, times of the significant events that occurred, questions asked by the users regarding the use of the system, perceptions of the user’s safety when using the system throughout the experience, use of the question navigation index, use of the “go to” functionality to navigate the questions, and interactions with the questions.

3.3 Procedure

The pilot was carried out in October of 2012. Unlike the first pilot in 2010 (Sánchez and Espinoza, 2012), on this occasion the pilot was performed on a date different from the regular process for taking the PSU. This particular pilot experience was implemented in the Metropolitan Region (Santiago de Chile), using the physical space in the Central Library for Blind People, located in Santiago, during a 4-hour session including usability testings.

The first stage of the procedure consisted of installing the workstations for the users involved in the second sample to utilize the AudioPSU system. Afterwards, the users entered the room, and were requested to sit down at an individual workstation. The composition and distribution of the contents of the PSU Language and Communication subject test on the AudioPSU software were explained, informing the users that the position of the sections was configured in the same way as it is presented to sighted users on the paper and pencil test. The software use instructions were read to the users, and the functionalities available through the numeric keyboard were explained. In this way, the facilitators provided initial support to the participants regarding the use of the system, mainly related to software navigation and exploration of the functionalities using the numpad. This process took 20 minutes. Once this stage had been completed, it was indicated that the time available to finish the test was 2 hours.

In order to support the use of the software, the user had access to supporting guidelines written in Braille or Macrotype (according to the degree of each user’s vision). These guidelines provided information regarding the operability of the AudioPSU application, in addition to the buttons used for the interaction. On this occasion, a copy of the test written in Braille was not provided, as happened in the first pilot application in 2010.

In order to evaluate the users’ performance in this second pilot, the facilitators in the room used the Non-Participant Observation questionnaire, recording information regarding the experience. In the same way, faced with any questions or concerns regarding the use of the software, the facilitators provided the user with the necessary help in order to be able to utilize the functions of the software.

After the test had been completed, the facilitators proceeded to apply the Software Usability Questionnaire, in order to learn more about the users’ evaluations regarding their use of the software.

3.4 Results

The results obtained from the 2012 usability evaluation, based on the application of the end user questionnaires, demonstrated considerable improvements regarding the average scores assigned to the various dimensions in the 2010 pilot (see Table 1). The “Satisfaction” dimension presented an average of 8.4 points (increasing by 1.4 points compared to the 2010 pilot evaluation). The “Control and Use” dimension presented an average of 8.1 points (representing an increase by 0.4 points compared to the 2010 pilot), and the “Sounds” dimension presented an average of 8.5 points (representing an increase of 1.9 points above the 2010 pilot).

In performing a T-Student statistical test of independent samples using the data obtained for both pilots, statistically significant increases in the usability evaluation were found for the “Satisfaction” ($t = -2.177$; $p < 0.05$) and “Sounds” ($t = -2.210$; $p < 0.05$) dimensions.

Although the increase observed for the “Control and Use” dimension was not statistically significant, just as in the other dimensions it presented a very high average score on its evaluation. It is worth highlighting that the averages for all three dimensions are above 8 points, within the upper portion of the range of possible values (above 75%), as the scale of evaluation on the end user questionnaire was from 1 to 10.

Table 1. Results of the end user questionnaire by dimension.

	Satisfaction	Control and Use	Sounds
Mean 2010	7.0	7.7	6.6
(Std. Dev.)	(1.64841)	(1.11184)	(2.37603)
Mean 2012	8.4	8.1	8.5
(Std. Dev.)	(1.1307)	(0.70679)	(1.17799)

The quantitative results obtained demonstrate the high degree of the tool’s usability. This is clearly shown by the results of the satisfaction category, the positive perception of users regarding control and use of the system, and the high level of interpretability of the sounds.

Regarding the open ended questions section, for the question, “Did you like the software?”, certain aspects were especially valued by the users, such as the ease of use, the use of the differentiated voices, the speed of the interaction and the overall clarity with which the software provided information. These aspects point to resources that allow for a higher degree of autonomy when taking tests, and higher levels of ease in understanding test questions and manipulating the test.

For the question, “What did you not like about the software?” some users felt that the tone of the voice and the low level of clarity regarding some words are aspects to be improved in the system. Some considered it important for users to have prior training before using the system. Considering that people who are blind and who use screen readers, for example, are accustomed to certain tones of voice, as are those with access to written content through oral readers, such training would be important for a user who is blind to be able to become accustomed to the tone of voice before taking the test.

When the users were asked what things they would add to the software, they mainly pointed to a speed control option for the voices, and to incorporate a set of different voices to choose from. These are resources that would allow the user to improve or personalize the application in accordance with his or her needs, and according to the nature and specificities of the test questions at hand.

Regarding the questions, “What do you think the software can help you with?”, and, “What other uses does it have?”, the users expressed opinions related to the fact that the software could be used to take other kinds of tests, and to read electronic documents.

Finally, and just as in the case of the first pilot experience, all of the users agreed that they liked using the numeric keyboard, as it is easy, fast and comfortable to use.

From the non-participant observations it is worth noting the autonomy of the users’ general performance. The system’s functions were adequately understood by the users, and very few questions were asked regarding the use of the tool, as the users tended to answer their own questions through the support of the system user’s manual and the keypad.

In the case of the system usability evaluations, it is worth noting that the pilot experience represented the first time that participating users interacted with the system, which further reinforces the results obtained. This result is similar to that observed for the first pilot experience, as the users identified the buttons of the numeric keyboard without any problems. However, becoming familiar with the functions of the software associated with

these keys took some time, and although in the context of the pilot 20 minutes of training was sufficient, in a real life situation it would be far better for users to get to know the tool before taking the actual test.

4. CONCLUSIONS

AudioPSU allows for the integration of users who are blind in taking the PSU test in normal testing rooms with sighted users. This was evidenced in the first pilot experience. This is due to the fact that the system provides information to the system's users only, without producing bothersome sounds or interrupting the work and concentration of others nearby in the test-taking environment. By maintaining the same test-taking format, users felt that they were finally considered capable of interacting in the same way as a sighted student does with the paper based test. In this way, AudioPSU is positioned not only as a tool for equal opportunity and access to the process, but also as a tool that does not require a segregated social environment in order to operate. In addition, specific conditions are not required that impede people who are blind from being included within the regular PSU test taking process. This represents an option that is different from a special process of application of this test, which is currently the only possibility for accessing higher education in the case of people who are blind.

The kinds of adjustments that were made to the pilot systems in 2010 and 2012 for students with visual disabilities were oriented towards changes related to accessing information. This is to say that the adjustments were related to moving from text-based formats to audio-based formats, through the use of software and devices that allow users who are blind to navigate throughout the entire structure of the instrument. In this way, as the sole proposal for modification, a different form of taking the test was proposed.

Without a doubt, one of the advantages of AudioPSU compared to the current system for assisted test taking of the PSU is the degree of autonomy that the software provides to people with visual disabilities. The system provides users with higher autonomy when navigating the test, making decisions, and provides a higher capacity for users to manage the use of time when responding to the questions, according to the audio-reading skills of each user.

Given the initially observed complications in the 2010 and 2012 pilots, related to understanding the operability of the system and the numpad, it was found that it would be necessary to perform prior training with the users, providing accessible material well before taking the actual test. This would allow them to become familiar with the different components of the system and their respective functionalities, similar to practice tests taken by sighted students.

The profile of the users that participated in both pilot experiences consisted of users who were already accustomed to the use of voice synthesizer assistance regarding their experience with computer use. For this reason, the application contains voices that facilitate a comprehension of changing context between different test questions, providing for a more fluid and user-friendly experience with the AudioPSU system.

According to the responses to the open ended questions obtained during the development of the second pilot experience in 2012, only two of the participants had had prior experience taking a practice PSU test. This implies that students with visual disabilities are generally unaware of the test structure, for which reason they do not have much knowledge of the kinds of questions or the extent of the texts involved, among other aspects. This leaves them at a disadvantage compared to their sighted peers.

There are certain requirements for working with AudioPSU, such as the ability to use the Braille reading-writing system. Two of the subjects who participated in the 2012 pilot were not trained in the Braille system, or had forgotten it due to the fact that they had stopped using it. This meant that it took them more time to understand the use of the numpad, which had been re-keyed into Braille. This is relevant due to the fact that the prevailing use of voice synthesizers for people who are blind is not sufficient, and it is necessary to further strengthen more than just one sensory channel in order to obtain and comprehend information.

The positive results of this pilot experience demonstrate the success of the initial adjustments regarding access to the information provided in the test. However, it is necessary to continue studying variables such as the level of reading comprehension, exploration skills and audio skills, among others. In this way, the data obtained is not sufficient to be able to affirm that the audio-based PSU establishes a comparable level of performance between students who are blind and sighted students.

Future work will study the main difficulties and points of advantage that students with visual disabilities experience when learning Language and Communication concepts.

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